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ON CERTAIN PECULIARITIES OF THE KNEE-JERK IN SLEEP IN A CASE OF TERMINAL DEMENTIA.

FROM THE LABORATORY OF THE MCLEAN ASYLUM, SOMERVILLE, MASS.

By WILLIAM NOYES, M. D., Assistant Physician and Pathologist.

In the more precise investigations of the physiological conditions modifying the knee-jerk all investigators have found that the mental condition of the normal subject entered largely as a disturbing factor, the different emotional states and the varying conditions of the nervous system invalidating the result to a certain extent, or at least rendering necessary an enormous number of observations before the "normal" knee-jerk for any individual could be obtained. Emotional states being almost completely absent in cases of advanced dementia it was thought that an investigation of the knee-jerk in this state might yield some results on the conditions modifying it. An excellent subject was found in an elderly man, admitted to the asylum in 1841, and with the exception of the seven years preceding 1850 having spent this whole period at the McLean Asylum.

In 1843 it is stated that his "mental faculties [are] mostly gone; never makes an inquiry; spends his time in wandering about the yard; slovenly in his dress;" and but little or nothing could be added concerning his mental condition at the present time. His dementia is complete, he having absolutely no knowledge of his surroundings, not even knowing his name, is unable to answer questions relevantly, his talk being utterly incoherent. He is good natured and docile and has never made the slightest objection to the experiments, which almost always mean an extra nap for him. In fact he

will go to sleep in almost any position in which he is placed, and remains perfectly quiet and contented. Several demented men were tried, but with the exception of this one they all proved resistive or restless, and were given up one after another. The patient finally selected was a peculiarly good one for a prolonged series of tests on the condition of his nervous system as he was subject to periods of depression and exhiliration, such as not infrequently occur in chronic dements, and a record was made of all his bodily functions, pulse, temperature, weight, blood pressure so far as this could be measured, mental condition, and finally knee-jerk in the hope of finding some change in his bodily condition coincident with the change in his mental state. Unfortunately, from the point of view of gaining any information on this particular point, after passing through one cycle of exhiliration and depression he settled down into a state of comparatively even mental and physical life, and as the observations taken during this cycle would need further confirmation no mention will here be made of them. The original problem, also, the theoretically lesser variability of the knee-jerk in a demented person, gradually changed into another as will appear subsequently, and the present paper will be confined to a consideration of two important points that came out in the course of the investigation.

Apparatus and Method of Experimentation.

After a trial of different hammers that of Lombard[1] was finally adopted, that of Prof. Bowditch[2], which was kindly loaned for an experimental trial not proving strong enough for this patient in whom a rather heavy blow was necessary. The hammer was of cast iron, the handle being an iron rod 20 cm. long, on the end of which a similar piece of iron rod 4 cm. long was fastened horizontally, serving as an axis and supported in an iron frame work. An index on the handle moved over a graduated scale, so that by raising the hammer any given number of degrees the same strength of blow was given. Throughout the experiments the hammer always fell 45°, except in a few instances where the strength of the blow was changed for a short time for some special purpose. The hammer was supported by horizontal rods and clamps to a piece of gas-pipe, serving as an upright support fastened to a firm wooden base that could be securely clamped to the table. The arrangement combined firmness and strength, while at the same time the hammer could be quickly raised or lowered,

[1] *American Journal of Psychology*, 1887, Vol. I., p. 12.
[2] Bowditch and Warren *Journal of Physiology*, 1890, XI, p. 27.

or moved in any direction horizontally, and thus easily adjusted to hang at zero of the scale, when the patient's leg was put in position. When pulled back into position to strike the blow the hammer was held by a large electro-magnet, the support of which was also adjustable. The hammer was pulled back by a cord and released by a simple circuit-breaking key. The blows were always given at 5 seconds intervals, except that the interval was occasionally changed for special purposes, but in the reports of the experiments 5 second intervals are always to be understood unless otherwise distinctly stated. The patient reclined on his right side on a mattress placed on a table, with a firm support extending the length of his back. The left knee was supported on a wooden arm extending from a wooden upright that was firmly clamped to the table, and the left foot was supported in a stirrup hanging from the ceiling allowing free movement of the leg. Attached to the stirrup at the point on which the heel rested was a steel rod 3 feet long, passing backwards and supported on pulleys; on its further end was fastened a thread passing over pulleys and attached to a short vertical steel rod, moving up and down through two brass supports, and suspended from above by a light spring. A cork placed on the rod carried on its side the writing point, a piece of light stiff celluloid, which pressed lightly against the drum of a Baltzar Kymograph. When the blow was struck the foot moved forward pulling the steel rod with it, and this by its thread attachment pulled down the writing point, leaving the record of the full length of the kick on the smoked surface of the paper. There was of course always a slight backward kick which appears in the records above the horizontal line made by the drum revolving under the writing point when this was at rest.

Disappearance of the Knee-Jerk in Sleep and the Effect of Auditory Stimuli.

The disappearance of the knee-jerk in sleep has been previously observed.[1] Its complete disappearance was early noticed in our patient and this is therefore no departure from the normal. As would naturally be expected the patient went to sleep much more easily than a person with an active mind, and it was thus possible to observe the phenomena a large number of times.

The behaviour of the knee-jerk when sensory stimuli are received by the patient during this period of sleep appears,

[1]Bowditch and Warren, loc. cit. p. 59.
Lombard, loc. cit. p. 53.

however, to be a distinct departure from the normal, and suggests that the weakened state of his brain permits the sensory stimulus to exert its effect in reinforcing the knee-jerk for a much longer period than in a person with a sound brain.

That the knee-jerk is increased when the patient clinches his hand or makes any violent movement coincident with the blow was first shown by Jendrássik[1]. "He also thought that stimulation of the sensory nerves had a similar influence on the tendon reflex, but considered his experiments on this point incomplete and that such an influence was more difficult of determination." (Quoted from Bowditch and Warren.)

Mitchell and Lewis[2] made a study of the conditions under which the knee-jerk is increased and diminished, and found that volitional acts directed to other parts of the body, painful stimulation of the nerves of the skin either by pinching or by the application of heat, cold or electricity, caused a reinforcement, as did also a burning magnesium wire exposed to the eyes.

Lombard found that sensory irritations, voluntary movements and strong emotions when synchronous with the blow increased the knee-jerk. The investigation of Bowditch and Warren had for its object a study of the exact relations in time between the knee-jerk and the reinforcing act, and was suggested by the statement of Mitchell and Lewis "that the muscular action or circuit closing, must precede the tap, in order to reinforce it, by a period which is, as yet, undetermined." The conclusion of Bowditch and Warren with regard to auditory stimuli was that "the effect of a sudden auditory stimulus on the extent of the knee-jerk was, in the three subjects of experiment, almost wholly positive, though great individual differences were observed. The maximum effect was produced when the interval between the sound and the blow was 0.2″—0.3″."

As the results here to be recorded have to do with the knee-jerk in sleep the experience of previous investigators on this point is of interest.

Bowditch and Warren[3] found that "the monotonous character of the experiment was often found to produce a decided tendency to sleep in the individual experimented on. To counteract this tendency and to insure a certain degree of attention to the phenomena, the subject of the experiment was required to declare after each knee-jerk whether or not a

[1] Jendrássik: Beiträge zur Lehre von den Sehnen reflexen. Deutsches Arch. f. Klin. Med. 1883, XXXIII, 177.
[2] *Medical News*, Feb. 13 and 20, 1886.
[3] Loc. cit. p. 58.

sensory-stimulus (i. e. sound, flash, etc.,) had been perceived, or in other words, whether the knee-jerk was normal or reinforced. In spite of this precaution the tendency to sleep was sometimes quite irresistible, and in eight or nine cases the experiment was continued after the subject had yielded to it and was sleeping soundly. It was then found that the knee-jerks, both normal and reinforced grew gradually smaller, and when sleep was profound, disappeared entirely, the blow upon the knee being absolutely without effect. This result is not what might have been expected from our knowledge of the effect of sleep on the ordinary cutaneous reflexes, e. g., that produced by tickling the sole of the foot. Whether this can be regarded as an argument against the reflex character of the knee-jerk, or whether we have here an essential difference between deep and superficial reflexes, are questions to be decided by future investigations."

Prof. Lombard has kindly gone over with me his own curves made in 1887 in New York, generally on healthy medical students, and many of these show an absolute disappearance of the knee-jerk in sleep, and they also show a sudden rise from 0 from some accidental stimulus such as the entrance of a person into the laboratory, but this effect lasted over but a few kicks.

In our demented patient when the knee-jerk has entirely disappeared in sleep an auditory stimulus causes an increase in the length of the kick, and this increase is visible over a long series of jerks. This latter phenomenon is apparently a departure from the normal and a peculiarity of this subject. This in well shown in Fig. 1. The patient was asleep from the beginning of the experiment and soundly asleep with total disappearance of the knee-jerk during the minute and three quarters preceding the time when two light taps were given on the table with the wooden handle of the needle that was being used by the observer to make records on the drum.

The knee-jerk rose from 0 to 9.5 mm.; in 5 seconds rose to 39.5 mm.; in the next 5 seconds to 59 mm.; then fell to 38 mm.; through the 29 succeeding kicks gradually fell with slight fluctuations to 6.5 mm.; remained at practically this length for 3 kicks; rose to 15 mm., and then to 28 mm.; fell to 16 mm. and 14 mm.; then came 5 kicks averaging 6.6 mm.; then came a rise without apparent cause to 44 mm.; then followed a fall to 0 after fluctuations extending over 27 kicks. Thus one auditory stimulus had an apparent effect extending over 72 kicks occupying 6 minutes. During this whole time the subject was sleeping soundly, being apparently as sound asleep as when the auditory stimulus was first given. Five kicks of the value of 0 then followed, and there then

came on another series of increased kicks with no apparent cause, lasting over 16 kicks, with another total disappearance. There then followed 28 kicks with almost total disappearance of the knee-jerk and then two taps (B) brought out the series of reinforced kicks again, with a peculiar series of groups of kicks extending to near the end of the experiment, with occasional total disappearances. Toward the end (C) two taps produced almost no effect, causing a rise only to 10 mm. from a preceding 7, then followed 18, 10.5, 4 and 0. After three of 0 value another lengthened group came on with no apparent cause, and at this point the subject was awakened by being spoken to. It was noted that this day he was decidedly more dull than on the day before, that he slept from the beginning to the time he was awakened, and that all efforts to rouse him at this point amounted to but little as he would simply mutter a little and then drop off to sleep again. There were no accidental sensory reinforcements that were sufficiently noticeable to be brought to the consciousness of the observer who was on the watch to note them. The peculiar set of "groups" of kicks occurring during the course of this experiment will be discussed later on.

This prolonged effect of a sensory stimulus is seen again in Fig. 2, where two clicks were given on a telegraph sounder at A, after the knee-jerk had entirely disappeared. Here the kick rose from 0 to 18 mm., and then to 42 and 44, falling through 17 kicks to 3 mm., not reaching 0 again for 17 more kicks. There were three kicks of the value of 0, a short rise over 4 kicks, a total disappearance during 2 more, the needle not even making a dot on the line, and then there came another of the "groups," B, with no apparent exciting stimulus, lasting over 10 kicks before these entirely disappeared again. There were slight rises above the 0 line, and at C a noise on the floor below caused another series of reinforced jerks, and the subject awoke. Practically this same effect of stimuli is seen in Fig. 3, where at A and B walking on the floor below caused the rises there shown; the much lesser effect of the second stimulus is seen in the fewer number of kicks that were caused by it. Blows were delivered at the regular 5 second intervals although without the effect of moving the needle from the straight line, until at C two taps with the needle-handle and a distant locomotive whistle a little later caused the prolonged series of increased kicks that followed. Here again it must be remembered that to all outward appearances the patient was sleeping as soundly as when the sensory stimuli were received. Fig. 4 shows the same effect once more, the knee-jerk having entirely disappeared during the period represented by the straight

line preceding A, blows being struck at the regular 5 seconds intervals, while at A, a passing barrow caused a slight rise and at B the noise of a passing cart caused a much greater rise, with a secondary rise a little later, with another rise before the knee-jerk entirely reached 0 again, and then after three kicks of the value of 0 there was still another rise, when there was again total disappearance.

In Fig. 5, the effect is shown of giving the rapping-stimulus seven times in succession. The largest effect was after the second time where the reinforcement continued over 13 kicks before the zero point was reached. After the third stimulus there were 8 reinforced jerks before the kicks sank again, not to 0, but to 4 mm. Stimulus no. 4 called out only two reinforced kicks, no. 5 called out 2, no. 6, 4, and no. 7, 6. At no. 8 the patient was awakened.

These would seem to show that the subject had gradually become accustomed to the stimulus and thus its effect was lessened. If it is argued that the patient was more wakeful at 6 and 7 as shown by the fact that the kicks did not return to 0, this would mean also that stimuli did not have so great an effect during this more wakeful condition as during the condition of deeper sleep. This diminution of the effect of a reinforcing stimulus is shown in Fig. 6 where 2 clicks were given on a telegraph sounder at (1), causing a marked effect lasting through 6 kicks, and then disappeared, to be followed by a secondary rise during 7 kicks, and then a total disappearance. A repetition of the clicks however at (2) was followed by no response for the first kick but the second and third kicks rose respectively to 1 and 2 mm., which ordinarily would be accounted for by the jarring of the apparatus, but in this particular instance there had been no movement even from the jarring, so it seems fair to attribute these two movements of the writing needle, slight as they are, to the knee-jerk. A third repetition of the stimulus (3) called out a knee-jerk of 3 mm., followed by a total disappearance during 5 kicks, then a kick of 8 mm. with no apparent preceding stimulus, a disappearance of three kicks, and then a repetition of the clicks, this time three clicks instead of two, produced a kick of 8 mm. with another total disappearance. A repetition of the three clicks (5) caused no response for the first kick, but the second rose to 26 mm., the third to 43, and from this time on there was no disappearance but a kick followed every blow of the hammer.

Attempts to find a similarly marked reinforcement from auditory stimuli while the patient was awake did not meet with as good results as while he was asleep. Fig. 7 shows a portion of a curve taken from the middle of a tracing while

the subject was fully awake. At the places indicated by dots two clicks were given on the telegraph sounder and an apparent reinforcement appears at times, and again an apparent inhibition. This disagreement may be due to the fact that the interval of time by which the sound preceded the blow was not measured, so that the blows may have been struck at the reinforcing interval at one time, and at the inhibiting interval at another. The irregularities in the kicks, during the period that the reinforcing signals were being given, are no greater than the irregularities in the kicks preceding and following the reinforcing signals. The sounds both inside and outside the laboratory, that had so much effect during sleep, never appeared to have a corresponding effect when the subject was awake. To have settled this point definitely would have necessitated a repetition of the elaborate experiments of Bowditch and Warren. Nor was the interval by which the sound preceded the blow in sleep measured; it probably usually varied between one and two seconds. As the peculiar prolongation of the reinforcement made its appearance apparently irrespective of the interval by which the sound preceded, particular attention was not given to this point. It would be interesting to determine if an interval could be found at which the stimulus would inhibit such a prolonged series of kicks as shown in some of the curves. On several occasions the first kick after an auditory stimulus did not rise as high as the second, as shown in Fig. 3, and this raises the question whether the inhibiting interval may not have accidentally been struck here, but the effect of the inhibition passing off during the succeeding 5 seconds, the stimulus exerted its full force and the kick rose to the maximum. Should this be so, it would seem to point to the necessity, in measuring the interval by which the blow must be preceded by the sensory stimulus to produce inhibition or reinforcement, of following the first blow by several more at comparatively short intervals. With regard to sensory stimuli that reached this patient during the time he was awake it can only be stated that these appeared to have a very slight and trifling effect compared with those that reached him during sleep.

It should be added that previous observers of the disappearance of the knee-jerk in sleep and of its rise in this condition in response to external stimuli have not delivered the blows at the same intervals as in these experiments, consequently it is possible that some of the effects of the stimuli may not have been recorded in their tracings. Attempts were made to settle this point by experiments on normal individuals, but the knee-jerk did not entirely disappear in sleep in the trials that were made. In Fig. 12 there is shown a

portion of one of these tracings from one of the medical house-pupils. The experiment was begun at 10.10 p. m. and continued until 11.15 p. m. The portion shown is from about the middle of the tracing, after the subject had become thoroughly drowsy, and a grdual diminuation of the length of the kicks is seen as the experiment progressed. When it became probable that the knee-jerk would not completely disappear the customary auditory stimuli, two taps with the needle-handle, were given at (1), (2), (3) and (4). Although there was a response in each case the effect of the stimuli extended over a much shorter period than in the demented patient. Beginning with the tenth kick preceding the point at which the stimulus was first given at (1), the length of the kicks in millimetres is given below.

5.5	2	2.5	10	7—(4)
5	3.5	9.5	7.5	14
5.5	4	2	3	5
5.5	14	2	3.5	8
3.5	9	2	3	2
10	5	5	3	7
4	10	7	7—(3)	6
4.5	6	15	4.5	10
4	3	4	3	7
15—(1)	5	15	15	9
8	2.5	4	3	6
13	15—(2)	5	4	8
4	3	12.5	2	6
				11

In each of the four cases the two taps were given immediately preceding the kick designated by the figures (1), (2), (3) and (4).

It will be seen that the effect of the first stimulus can be traced over the three following kicks, and then the knee-jerk fell to 4 mm. The second stimulus caused a rise from 2.5 mm. to 15 mm., but at the next kick the knee-jerk fell to 3 mm. The third stimulus caused a rise from 3 mm. to 7 mm., and the next kick fell to 4.5 mm. As the effect of the stimuli was evidently diminishing, the fourth stimulus (4) was made much louder than the preceding ones, and the knee-jerk rose from 2 mm. to 7 mm., and then to 14 mm.; the succeeding three kick were 5 mm., 8 mm., and 2 mm.

In no instance did any such prolonged effect from the stimuli occur as is shown in the tracings from the demented patient. Fig. 12 also shows the "groups" of kicks that could not be identified with any external stimulus; these groups are well shown before the stimuli were given by the two taps. During the time that these groups appeared the subject was in the same condition of half-sleep as when the groups came out best in the demented patient.

It was possible on several occasions to find well marked evidences of this rhythm while the subjects were fully awake. Fig. 11 is a tracing from the demented patient while awake, and the wave like movement of the tops of the kicks is very evident.

As has already been stated there were suggestions of this rhythm (?) all through the tracings, from the first of the experiments, even during the waking state; but in none of the other tracings during the waking condition is it as well shown as in Fig. 11. This same suggestion of a rhythm is also shown in Fig. 13, which is of a tracing taken from a case of well advanced general paralysis. This patient was in the quiet and apathetic stage of the disease, much demented, with ataxic gait, and slow, stammering speech. He was awake during the whole experiment. The same wave-like appearance of the ends of the knee-jerks is well marked.

A tracing from still another patient is shown in Fig. 14. This man was a case of dementia, but not nearly so far advanced as the first case. He was awake during the experiment. There is seen the same suggestion of the wave-like motion of the ends of the knee-jerks.

A point not immediately connected with those already discussed, but having a bearing on the general question, is illustrated in Fig. 15, which is a portion of a tracing from the first case of dementia. The subject was fully asleep as is seen from the total disappearance of the knee-jerk during the first part of the tracing shown. At R the hammer fell out of time, interrupting the regular 5 seconds interval, and as a result of this disturbance of the regularity of the blows the knee-jerk rose during the next four kicks. At R^2 the rhythm of the blows was intentionally interrupted, with the result of causing a rise in the knee-jerk again, but this time less than at first, showing that the nervous system had become accustomed to this change of rhythm. At R^3 the blows were delivered in as quick succession as possible, causing a much greater increase of the knee-jerk than on either of the other two occasions; after eight blows given at the regular 5 seconds interval the knee-jerk again sank to 0.

Rhythmic Grouping.

Besides showing the peculiar prolongation of the effect of a sensory stimulus Fig. 1 shows also the peculiar "groups" of kicks that appear in the curves with no apparent auditory stimulus to account for them. One is tempted to speak of these groups as falling into a rhythm, but they do not occur under circumstances justifying one absolutely in making this claim. Yet looking at this curve as a whole it is difficult not

to think that there must be some rhythmic periodical activity of the body to produce these wave-like rises and falls. It will be seen that there were four of these groups before the auditory stimulus was given at A and the blows at the beginning of the experiment appear to have begun at the top of one of these crests. After the effect of the stimulus given at A had disappeared two of these groups came on before the second stimulus was given at B, and after the effect of this had disappeared the groups continued to appear to the end of the experiment. It is to be noted in this connection that the reinforcement at A came at about the time when a "group" might have been looked for, and the question arises did the auditory stimulus simply intensify one of these periodical rises in the knee-jerk. At none of the places where these rises came on, except at A, B and C were there any reinforcing stimuli to account for them. At B also the stimulus appears to have come at about the time when a rise was due, while at C the stimulus seems to have come between two groups, and this may account for the fact that there was a shorter effect of the stimulus here than at A and B.

In examining the remaining diagrams showing the prolonged effect of sensory stimuli to see if one of these "groups" may have entered as a disturbing factor the only instance where this could be thought to do so is in Fig. 4 where the secondary rise after B may possibly be looked on as a "group," but the prolonged reinforcing effect of the stimulus at B is nevertheless sufficiently well marked. The "grouping" is again well shown in Fig. 8. The series is taken from the middle of a tracing after the patient was fully asleep. There was an interval of seven minutes between the first kick and the preceding one, and the first blows after this interval of rest naturally acted as a reinforcement, but the kicks soon diminished, and the peculiar wave-like movement of the curve developed. There were no sensory reinforcements from sounds and the subject seemed to be in the soundest sleep.

The same phenomenon is seen again in Fig. 9, where there were no sensory stimuli except at 1 where two taps were given, and at C where a passing train of cars was heard. This shows also that the two taps did not invariably call out the prolonged reinforcing effect that usually followed.

It was possible on some occasions to account for the changes by variations in the depth of sleep, as in Fig. 10. Here at the points marked A there were no auditory stimuli to account for the rises, but in the intervals, at the points marked B, there were audible evidences of the soundness of the sleep. Usually however it was not possible to detect such a change, and the waves rose and fell without any noticeable change in the regularity of the respiration.

The question as to the cause of this rhythmic (?) grouping of the knee-jerks in sleep is a very interesting one, and considerable attention was given to it in attempting to find an explanation. The phenomenon was noticed very early in the experiments, and many of the tracings made while the subject was awake suggest this same tendency to a periodicity. The "grouping" always shows best, however, in a condition that might be termed half-sleep, where the subject is to all appearances sound asleep, but that he is not in the profoundest sleep is shown by the fact that his knee-jerk is not entirely abolished. Attempts were made to find some connection between these "groups" and the respiratory rhythm, and the respiratory curve and the knee-jerk curve were taken simultaneously, but the results were entirely negative, no particular length of kick being found associated with a particular phase of the respiratory curve. The attempt was also made by taking a plethysmographic tracing from the arm, to find some connection between the depth of sleep and the variations in the knee-jerk, but these at first were equally unsuccessful. Later it was suggested that there might possibly be some connection between the groups and the Traube-Hering curves, and acting on this suggestion additional plethysmographic tracings were taken. A glass plethysmograph, suspended from the ceiling to allow free movement, was placed on the patient's left arm, and connection was made through a glass tube having rubber joints with a very sensitive Marey tambour, the writing-needle of which was placed directly over the writing-needle of the knee-jerk apparatus, so that the two curves were made synchronously on the revolving cylinder of the kymograph. The Traube-Hering curves did not always appear, and there were also many times when the peculiar "groupings" did not appear, as it was necessary for the patient to be in the condition of half-sleep already alluded to, and also that there should be few or no disturbing noises. The necessary conditions have been fulfilled on repeated occasions, however, and a series of tracings obtained where there is a good Traube-Hering curve and also a good series of "groups" of knee-jerks. A portion of one of these double curves is shown in Fig. 16. The pulse beats are well marked and the respiratory rhythm is also well shown. The jarring of the blow of the hammer was sufficient to set the needle of the Marey tambour violently oscillating, so that the respiratory rhythm appears to be unduly accentuated, but this sharp upward rise is due to the vibration of the needle. The Traube-Hering curve is also well marked, the tops and bottoms of the waves being connected by straight lines. It will be seen that there is an

apparent coincidence between the two curves—that the Traube-Hering curve descends lowest in that part of the "group" where the kicks are longest, and at places where the Traube-Hering curve is highest the knee-jerks are much diminished. A rise in the Traube-Hering curve means of course increased blood pressure in the arm, and a fall in the curve corresponds to diminished blood pressure. On Mosso's theory that increased blood pressure in the extremities means lessened blood pressure in the central nervous system we should have, during the time that the Traube-Hering curve is at its height, relative anaemia of the brain and cord; and during the time that the Traube-Hering curve is lowest relative hyperaemia of the brain and cord. There are objections to Mosso's theory, however, as it fails to take into account the abdominal circulation, and the possibility that a change of blood pressure in the extremities may mean simply an opposite change in the abdominal cavity and not in the central nervous system.

Could we adopt Mosso's view it would simplify the problem greatly to say that if we got a rise in the Traube-Hering curve this would mean a diminished blood supply to the brain and cord, and a fall in the Traube-Hering curve would mean a corresponding increase of the blood supply of the central nervous system. The diminished knee-jerk would then naturally follow from the lessened functional activity of the spinal cord at the height of the peripheral Traube-Hering wave, while an increased knee-jerk from increased functional activity of the cord would follow at the low phase of the peripheral Traube-Hering curve. The occurrence of the high phase of the Traube-Hering curve with a diminished knee-jerk, and of the low phase with an increased knee-jerk has been noticed with sufficient frequency to give considerable probability to the theory that there may be a constant relation between the two. The Traube-Hering curves shown in Fig. 16 demonstrate that there is a rhythmic rise and fall in the blood pressure of the arm, as has been frequently proved before. There is thus naturally good reason to infer that with this rise and fall occurs throughout the whole vascular system, and that the vascular supply of the central nervous system is subject to this same periodicity. It also seems perfectly fair to assume that this rhythm might not necessarily be the same throughout the whole vascular system of the body. We only need assume that the vaso-motor centre in the medulla sets up the rhythmic contractions and dilatations in the vascular system that show themselves in the periphery in the Traub-eHering curves, but this rhythmic influence would not necessarily propagate itself throughout the whole

body within the same time, the vascular system possessing considerable inertia, and the amount of blood to be influenced being so great. Several rhythms differing in time might easily be present in the vascular supply of different portions of the body, dependent on the different rates at which the vaso-motor influence had propagated itself through the arterial system; such rhythms should show the same general characters with regard to rise and fall. Fig. 17 shows the result of assuming that this rhythm in the central nervous system differs a little in time from the rhythm in the peripheral circulation. In Fig. 17 the Traube-Hering curve shown in Fig. 16 has been moved back a distance representing 20 seconds in time, which would mean that the vaso-motor influence affected the blood supply of the central nervous system 20 seconds before it reached the arteries of the periphery, which seems a not improbable supposition. Although even with this change, the crests of the Traube-Hering wave do not absolutely coincide with the points of the greatest diminution of the knee-jerk curve, and vice-versa, yet the coincidence is much more striking, and additional weight seems to be given to the inference that there may be some connection between the two curves. It will be noticed that at one point of the knee-jerk there was a disturbing factor caused by the slamming of a door below, at A, sending the knee-jerk up at this point, and thereby apparently making the summit of this knee-jerk wave farther along than it otherwise would have been.

In Fig. 18 there is a much closer coincidence in the two waves than in Fig. 16. Here the Traube-Hering curve makes a long descent between 4 and 5, with a still longer ascent to 6. Again it is to be noted that at 4, where the Traube-Hering wave descends lowest, the knee-jerk curve is also longest.

The same general coincidence of the two curves is again seen in Fig. 19. This was one of the earliest tracings, and the writing needle of the Marey tambour, connected with the plethysmograph, did not make as good a record as it did later. At the end of the record the patient fell into his deepest sleep with the entire disappearance of the knee-jerk. It is interesting to note that, although the Traube-Hering curve continues after the knee-jerk has entirely disappeared, yet at no point does the Traube-Hering wave descend as low as at A, where there was the longest group of kicks. As in Figs. 16 and 17, there is the same number of waves in the knee-jerk curve as in the Traube-Hering curve.

Fig. 20 is from another of the early tracings, but it serves to show the same general characteristics that have been brought out by the other curves. At A a secondary wave appears on the long descent between 6 and 7, and slight cor-

responding changes may be noted in the knee-jerks below.

All the plethysmographic tracings given were taken from the left arm. As it would be valuable confirmatory evidence to obtain similar tracings from the leg, a tin plethysmograph in the shape of a boot was made, and in this the patient's right foot and leg were placed; the rubber band that served to keep back the water coming just below the knee. (Into each plethysmograph water of 30° C. was poured to take up the extra air space not occupied by the leg and arm. The water did not quite fill the plethysmographs, a small air space being left at the top to allow free access of the air to the opening communicationg with the glass tube and Marey tambour. A much better tracing was made by the writing needle with the water in the plethysmograph than with this empty, as the pulsations were thus confined to the small body of air directly above the water, and the arc of vibration of the needle correspondingly increased). The leg plethysmograph was suspended from the ceiling in the same way as that for the arm, and it was still possible to have the left leg, which was still the upper one, in the same position as before for the knee-jerk experiments. Tracings were then made showing synchronous right leg and left arm plethysmographic curves and the left knee-jerk curve. It was found, however, that the jarring of the blow of the hammer on the left leg communicated itself through the bony pelvis sufficiently to affect the right leg in the plethysmograph, causing a serious vibration of the needle with each blow, interfering with the production of a good curve. The arm and leg plethysmographic curves were then taken without the knee-jerk curve with better results, and a general correspondence was found. The leg plethysmographic curve was never as satisfactory as that of the arm, for it was possible to place the whole arm in the plethysmograph, the strong pulsation of the radial artery being strong enough to give a well-marked tracing, but no similarly strong pulsation could be obtained from the foot and calf of the leg. While, therefore, the experiments with the leg plethysmograph need to be carried farther, yet so far they point to similar results as with the arm.

Should the conclusions suggested by the knee jerk and plethysmographic curves seem to be justified, and should they be borne out by further research, the knee-jerk would thus be brought into connection with the other rhythmical and periodic activities of the body. The vaso-motor influence that produces the Traube.Hering curves is necessarily constantly active, but its effects are usually obscured by many other conditions. It would appear probable on *a priori* grounds that the Traube-Hering curve would come out more clearly where

the cerebral influence was removed or inhibited, and we find the Traube-Hering curve coming out with marked distinctness in our demented subject. For the same reason we should expect any phenomenon associated with the Traube-Hering curve also to come out better in such an individual than in a normal subject, and so we find the "groups"—if the relation to the Traube-Hering is a true one — coming out in this same patient. As the Traube-Hering curve is constantly influencing the normal respiratory rhythm, may we not also assume that the Traube-Hering knee-jerk curve, if it is permissible to call it such, is also constantly influencing the knee-jerk? This would explain the mysterious "rhythm" that has seemed to be present in many of the earliest knee-jerk curves taken in this patient, even when awake. We are led from this to a consideration of the knee-jerk of normal individuals, and if the inferences as to the influences affecting the knee-jerk in this demented man are legitimate, it is not evident why the same inferences do not apply to the normal subject. If this is the case then the original point of the investigation no longer has any bearing,—that is, the question as to the theoretically lesser variability of the knee-jerk in a demented person than in a healthy individual; the tops of the knee-jerks of a dement forming theoretically a straighter line than in a sound person. The "normal" knee-jerk curve, therefore, could no longer be considered as theoretically a straight line, but as a true curve correspondingin general with the Traube-Hering curve. It must be admitted at once that it is extremely doubtful if this can ever be shown on a normal individual with the constantly varying emotional condition of healthy persons; nor does it seem scarcely more likely that a normal individual will show such curves even in sleep as are seen in this patient, for the reason that the cerebral influences in a sound person would probably mask this ebb and blow; but this is mere conjecture and must be submitted to actual experiment.

It remains to add that if the "nervous force" or "irritability" of the spinal cord is really subject to this rhythmic action, the question is at once raised if the higher cerebral activities, especially the attention, are also subject to a similar rise and fall, for if the rhythm (?) already described be really due to a vascular process of vaso-motor origin, this same influence must affect also the functional activity of the brain itself.

Conclusions.

The chief interest in the results brought out in this paper lies in the fact that the experiments were conducted on a person whose mind has been weakened by dementia of many years

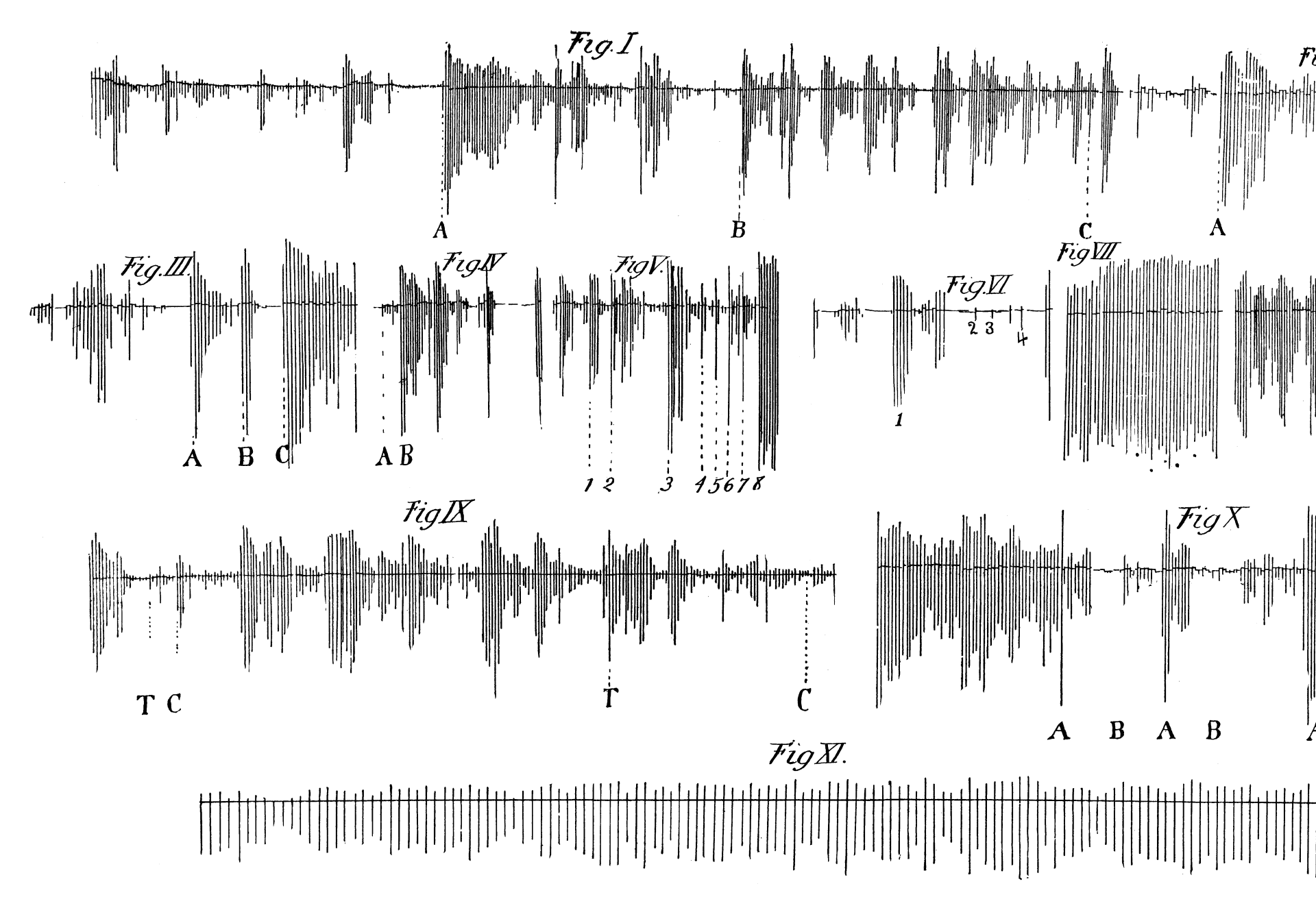

Fig. I
A
B
C
A
Fig. III.
A
B
C
Fig IV
A B
Fig V.
1 2 3 4 5 6 7 8
Fig VI
1
2 3
4
Fig VII
Fig IX
T C
T
C
Fig X
A B A B
Fig XI.

Fig. II.

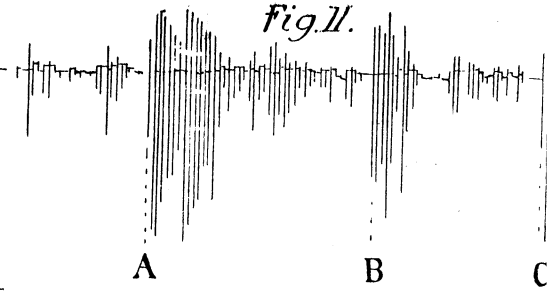


Fig VIII

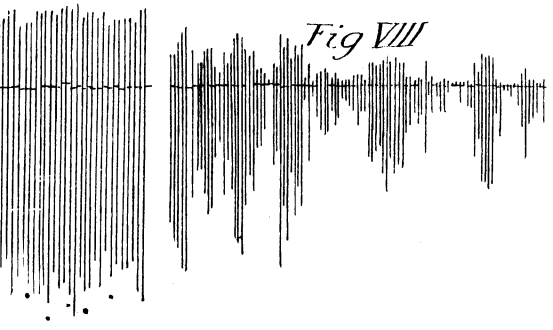


FIG. XII

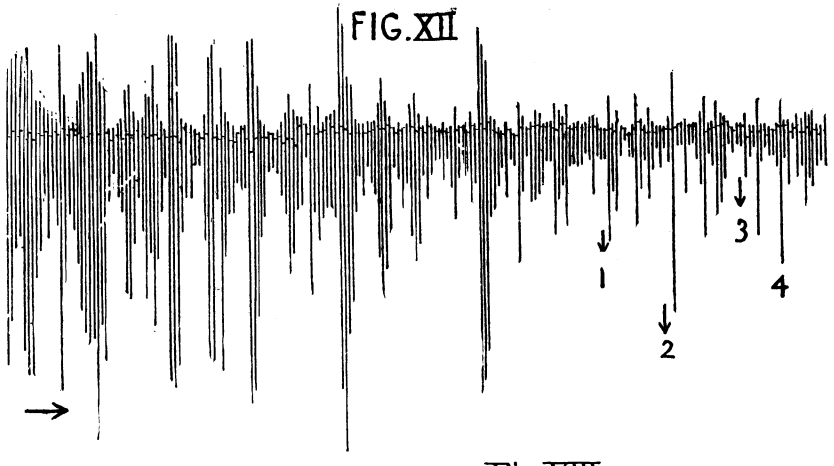


Fig. XIII.



Fig X

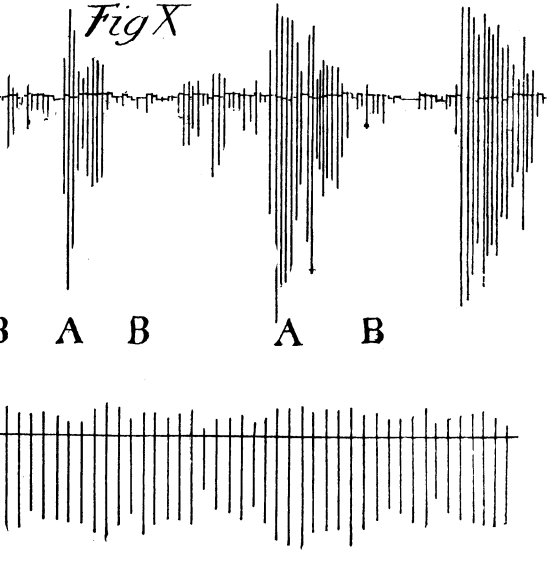


Fig. XIV.



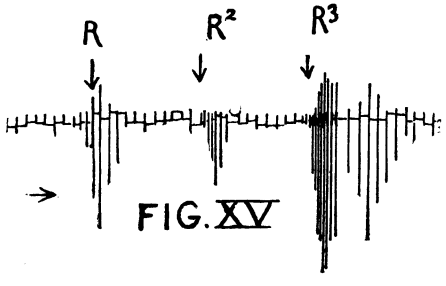


FIG. XV

FIG. XVI

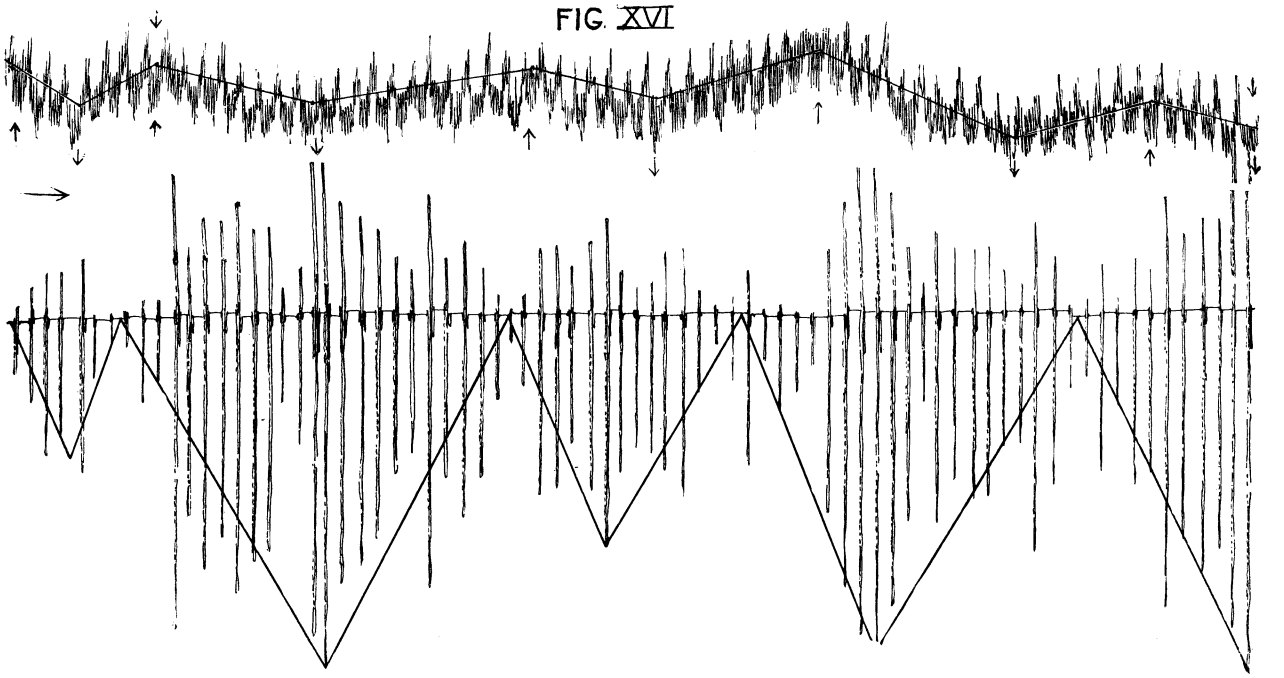


FIG XVII

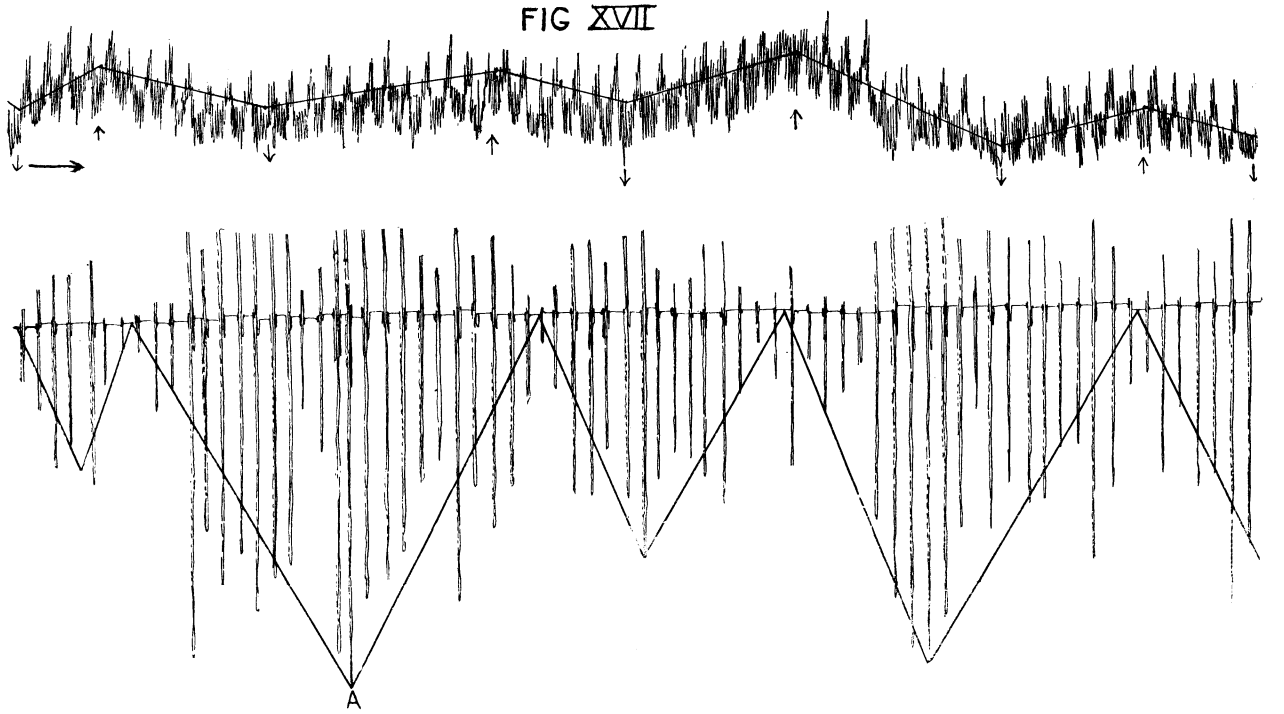
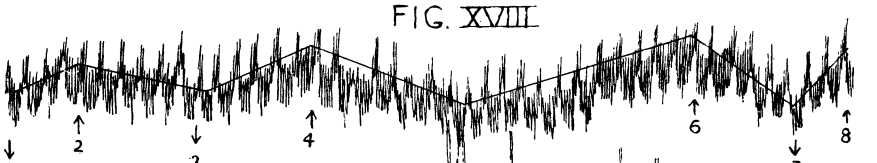


FIG. XVIII



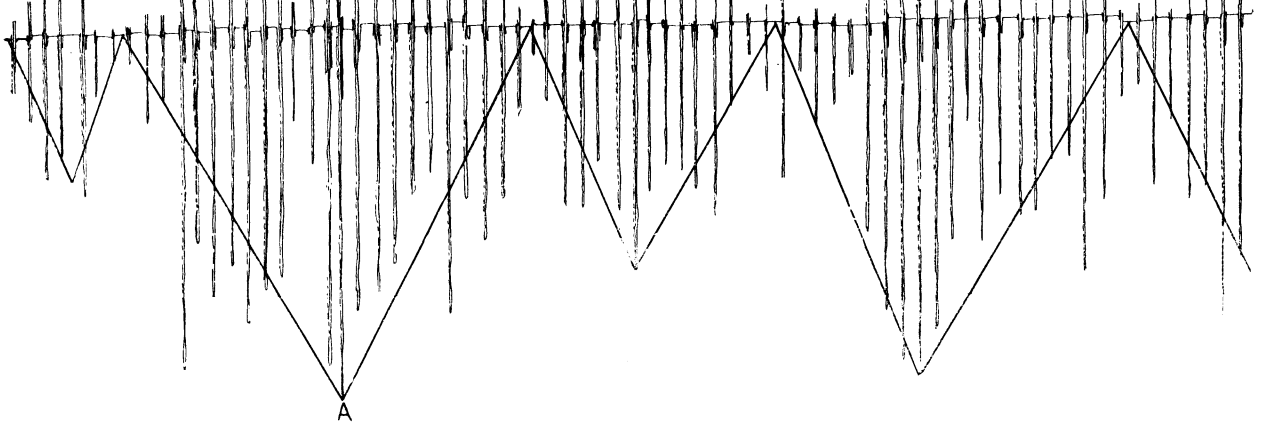


FIG. XVIII

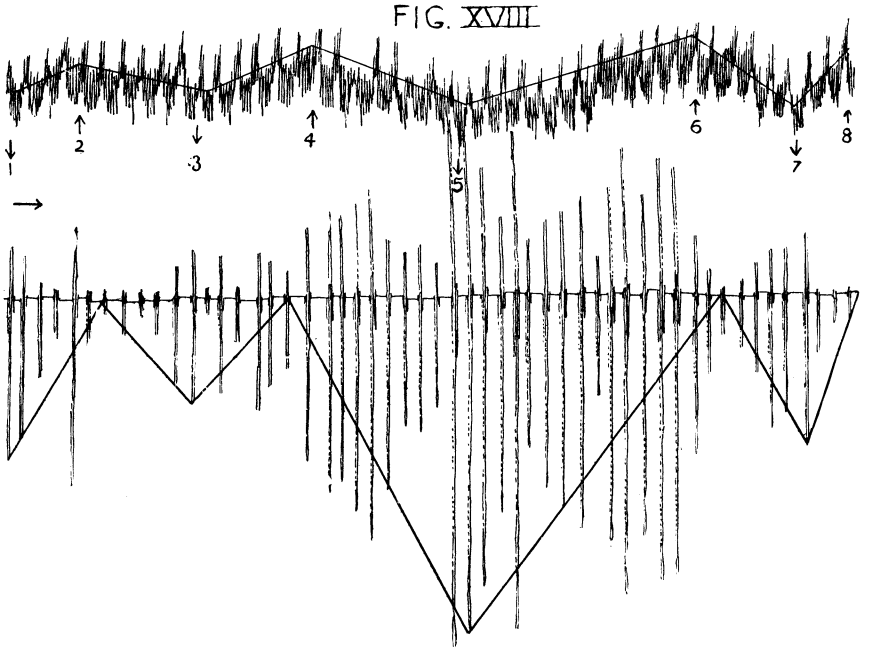


FIG. XIX

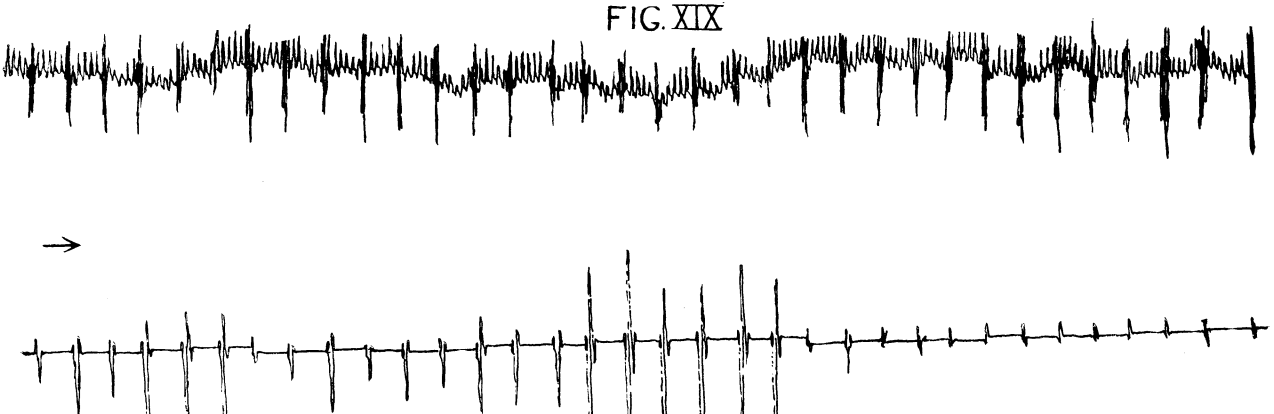


FIG. XIX

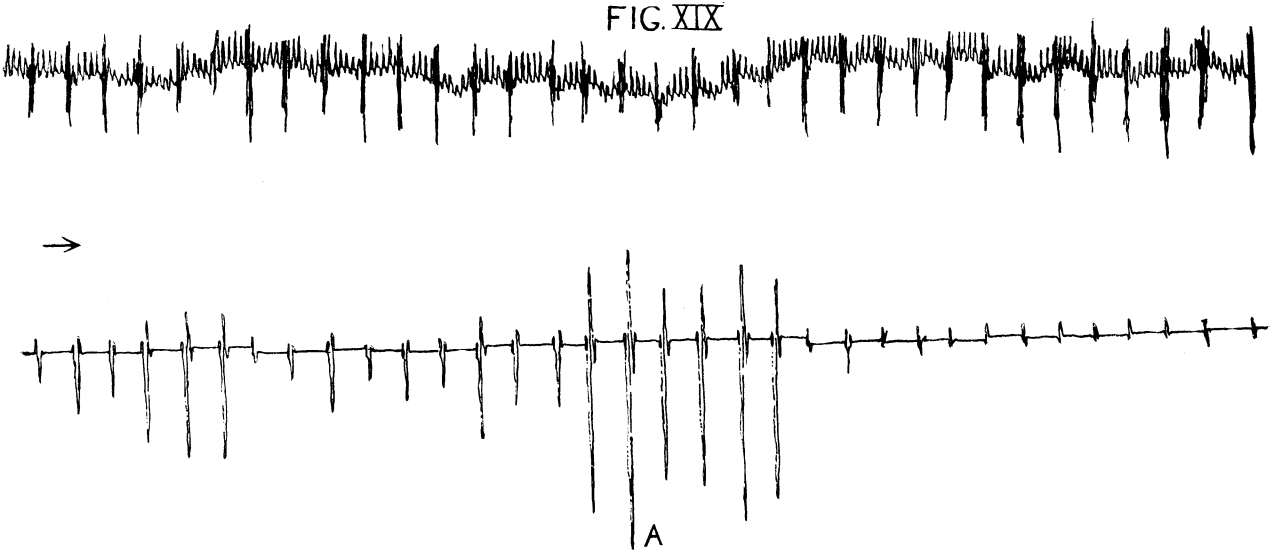
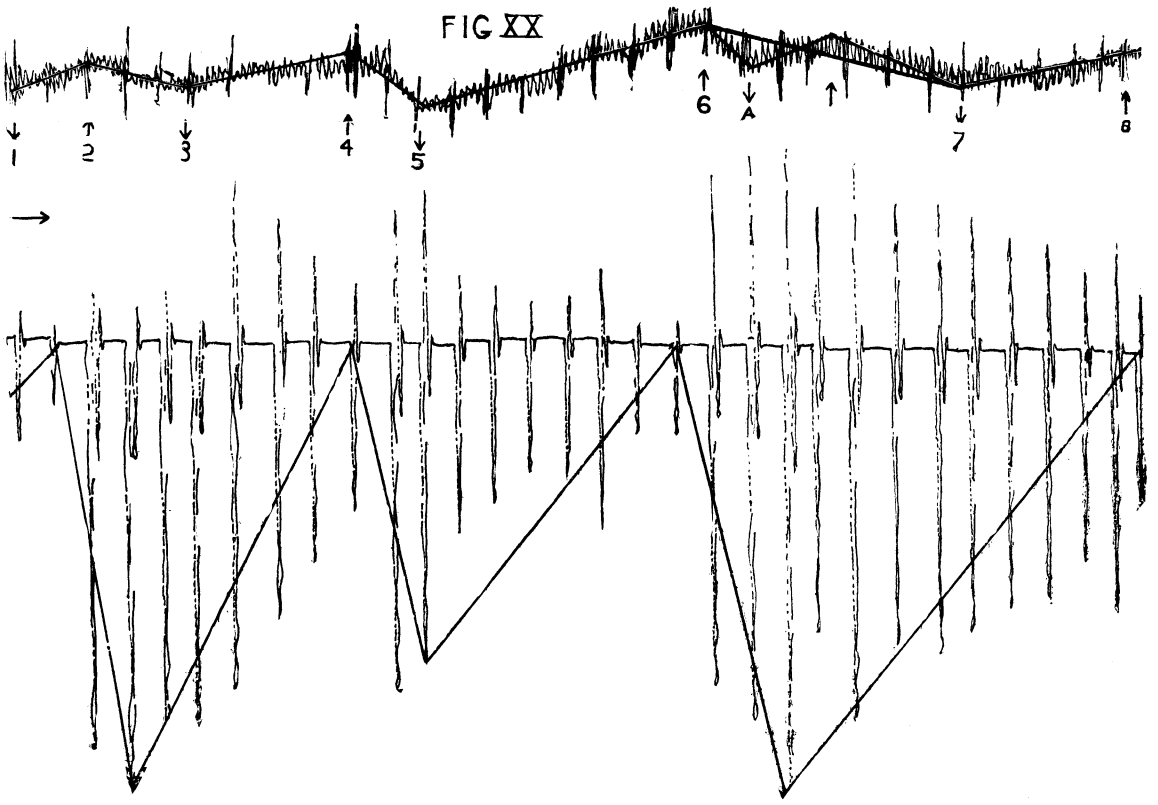


FIG XX



duration, and that this individual shows a greater susceptibility to sensory stimuli than persons in health. The most reasonable explanation of this seems to be that there has been a weakening of the inhibitory influence normally exerted by the brain over the lower centres. The remarks of Mitchell and Lewis[1] have so much bearing on this point that they may properly be quoted here. In discussing the cause of the increase of the knee-jerk from sensory stimuli, they say "It is very difficult to explain the fact that electricity, sensory impressions, and distant voluntary muscle acts increase the knee-jerk and the response to the muscle blow. If we conceive of a series of inhibitory centres extending from the mesocephalon all the way down the cord, and infer that all the agents mentioned are capable, by more or less paralyzing these centres, of releasing the active reflex groups below them, we shall be able to comprehend that the centre thus set free may, by increasing tone, give to the muscle a suddenly enlarged capacity to respond to the tendon taps or the muscle blow. Nearly all the facts with which we are concerned may be explained by inhibition organs and the effects produced upon them. On the other hand, it is equally conceivable that whenever a sensation reaches the cord or brain or both, an overflow occurs, which shall, by increasing the excitation of the centres, be felt throughout the body, and reinforce any organs chancing to be synchronously otherwise excited from without. Under this view we conceive of the nervous force as not confined entirely to the direct paths between the centres and the muscle to be moved, but as overflowing so as to pass through numerous ganglia, adding a certain small increment to their effects when in a state of such activity as the spinal toning centres must be at all times. The tone centres thus stimulated send out a higher wave of excitability to all the muscles, and if at the time this reaches a muscle, that muscle is being excited by a tap, there is an increased response."

Assuming such inhibitory centres as Mitchell and Lewis describe, these would only be kept up to their full functional activity by the healthy condition of the whole nervous system, so that when these inhibitory centres are under a weakened cerebral influence, as in dementia, they offer less resistance to what Mitchell and Lewis call the paralyzing influence of sensory stimuli. In the normal healthy individual in sleep a sensory stimulus preceding a blow on the patellar tendon produces a rise extending at most over a few kicks. This is certainly the most economical method for the individual, if we consider that it is beneficial that the effect of the accidental stimuli that are continually assaulting the nervous system

[1] Loc. cit. p. 203.

should be prevented from spreading over a wide territory or through a long time. In our demented patient a stimulus produces an effect extending usually over a much longer time, even so long as three minutes.

The experiments appear to give a graphic demonstration of the greater susceptibility to sounds, and all external stimuli, in persons with enfeebled, but not organically diseased, nervous systems. If this susceptibility to long continued effect of sensory stimuli in this patient is really due to weakened cerebral inhibitory power, it seems not improbable that the same effect must be produced in individuals with brains weakened or exhausted from any cause,—not necessarily from insanity. The large class of neurasthenic individuals naturally first occurs to one, and the question arises whether, when such patients "feel every sound in their back," this is not due to the uninhibited propagation of accidental external stimuli to the lower reflex centres, as shown in these knee-jerk curves. If so, the therapeutic corollary to this proposition, the necessity of excluding to the greatest possible extent all accidental stimuli from such patients, is graphically demonstrated in these curves.

The conclusions with regard to the so-called rhythm have already been discussed.

The results of the experiments may be summarized in the two following propositions:

In a case of terminal dementia of many years duration a series of experiments on the knee-jerk tend to show that:

1st. Sensory stimuli received during sleep produce a much greater effect and diffuse over a much longer interval than in healthy individuals.

2nd. In a condition of half-sleep when the patellar tendon is struck by blows of uniform strength at five seconds intervals, the knee-jerks fall into groups, and synchronous plethysmographic tracings suggest that these groups have some connection with the Traube-Hering curve.

If the truth of the second proposition can be conclusively established, several important corollaries would seem to follow. These are here stated as facts for the sake of presenting definite propositions, the truth or falsity of which must be submitted to further experimental investigation.

(a) The knee-jerk curve, instead of being theoretically a straight line as has been heretofore assumed, is, in reality, a curved line, with the general characteristics of the Traube-Hering curve.

(b) The spinal cord is not constantly in a condition of the highest potential functional activity, but its activity is represented by a curve of rhythmic vascular contraction and dila-

tation. During the phase of contraction of the spinal arteries, the spinal cord is at its least functional activity, due to a condition of relative anæmia, while during the phase of dilatation of the spinal arteries, the spinal cord is at its greatest functional activity, due to a condition of relative hyperæmia.

(c) The question inevitably raised by (b) is whether the higher activities of the brain are also subject to a rhythmic rise and fall synchronous with vascular dilatation and contraction.

It remains to express my obligations to several who have assisted me in the details of the work, and to extend my thanks to my colleague, Dr. D. H. Fuller, and to Drs. Abbot, Young, Fitz and Sawyer, medical house-pupils, for their assistance. To Dr. Fitz I am especially indebted for assistance and suggestions in regard to apparatus.